Schumpeter and the knowledge-based economy: on technology and competition policy

Schumpeter and the Knowledge-Based Economy: On Technology and Competition Policy

Luc Soete[a], Bas ter Weel[b]

[a] *Department of Economics and Maastricht Economic Research Institute on Innovation and Technology (MERIT), P.O. Box 616, 6200 MD, Maastricht, E-mail: luc.soete@algec.unimaas.nl*

[b] *Maastricht Economic Research Institute on Innovation and Technology (MERIT), P.O. Box 616, 6200 MD, Maastricht, E-mail: b.terweel@merit.unimaas.nl*

Abstract

This paper discusses some of the new policy challenges raised by the trend towards the knowledge based economy. It is argued that this trend signals a further weakening of old "market failure" arguments in guiding public action in the field of science, technology and innovation policy. Rather a Schumpeterian perspective on technical change recognizing the intrinsic differences in the nature of the accumulation process across sectors and industries appears more and more warranted. Such an approach does, however, require from policy makers to pay much greater attention to the effectiveness of their policy tools with a focus on policy and institutional learning, rather than following a set of simple normative guidelines about market failures. While such policy and institutional learning can and has to some extent already been implemented in most of Dutch technology policy and is a focal point of OECD comparative analysis (best practice, bench marking), it is much more difficult to introduce at the European level.

Key Words: Competition; Innovation; Knowledge; R&D

Introduction

Science and technology has been the subject of public interest and support for Centuries. The acceptance of a utilitarian argument for the public support of basic scientific research actually predates the Industrial Revolution itself.[1] It is impossible to review in this short paper the innumerable contributions which have been made over the last decade on both the *raison d'être* and intrinsic limits of public support for science and technology. But there is little doubt that some broad trends can be identified. An early trend away from the centralised public support for “big science” areas often considered of strategic importance: military research, atomic energy research, aeronautics and later on within the framework of the notion of so-called “pre-competitive” research support, new sunrise sectors such as microelectronics. A more recent shift in the nature of the public support away from technology push support towards more demand pull programmes with greater acceptance of the crucial role of users and the intrinsic recognition that technical success does not necessarily imply economic success. The Commission’s recent Green Paper on Innovation (EU, 1996) provides probably the most explicit recognition of the need for this shift towards innovation policies describing Europe’s failure in developing new products and new technology based firms as a European technology paradox: excellence and strength in basic and fundamental research yet failure to translate this in commercial excellence and success. And finally a growing recognition that technical change is in our current highly developed, open societies a complex dynamic process that involves many social and economic factors and a wide

[1] The first clear and forceful advocacy of a national science and technology policy based on public support for research is usually attributed to Francis Bacon (1627). In *The New Atlantis*, he advocated the establishment of a major research institute ("Salomon's House") which would use the results of scientific expeditions and explorations all over the world to establish the "knowledge of causes, and secret motions of things". See in more detail Freeman and Soete (1997) Part IV which gives a detailed overview of the historical development of public support for science, technology and innovation.

range of individuals, institutions and firms. The capacity of an economy to derive competitive advantages from technical change and innovation is in the end dependent on the dynamic efficiency with which firms and institutions can diffuse, adapt, and apply information and knowledge.

In this short paper we will focus in particular on this latter trend. The first two are by now well recognized even if they remain the subject of sometimes strong and even violent argumentation.[2] Furthermore, the recognition of the complexity of the issue challenges policy makers, in particular those which like to follow simple normative rules about the need for public intervention. As argued by one of us some 10 years ago:

> *"The anatomy of market failure discussion in neo-classical economics is indeed focussed on equilibrium conditions of stylised market systems. What the chapters in this book suggest, in line with evolutionary thinking, is that such a discussion should properly focus on problems of dealing with and adjusting to change. It involves in the first instance abandonment of the traditional normative goal of trying to define an 'optimum' and the institutional structure that will achieve it, and an acceptance of the more modest objectives of identifying problems and possible improvements. In part it also represents a more general acknowledgement that notions like 'market failure' cannot carry policy analysis very far, because market failure is ubiquitous."* (Nelson and Soete, 1988, p. 632).

---

[2] See e.g. the debate between Paul David and Paul David (and Ben Martin, Paul Romer, Chris Freeman, Luc Soete and Keith Pavitt in Kealey (1998).

From this perspective, and as we briefly discuss in Section 1, the current debate on science, technology and innovation policy will have to recognize to a much larger extent some of the new structural features of what is now largely recognized as the trend of our societies towards a knowledge based economy. This renewed recognition of the importance of “knowledge” is based as we argue in Section 1 on three factors. It raises some fundamental new policy challenges which can in our view, and as argued in Section 2, best be answered using more explicitly some Schumpeterian concepts based on both new growth theoretical contributions as well as on more appreciative, structural descriptions of sectoral technological developments represented for instance in Richard Nelson’s recent Tinbergen lecture (Nelson, 1999). In Section 3, we then turn to some empirical facts and figures. Again the very large number of reports which have been published on this subject cannot be reviewed, hence we only select some particular indicators to illustrate some of the intrinsic paradoxes and the possible way forward. We conclude by answering the following question: “What is the most effective competition policy framework?” and raising some broader - also in a geographical sense - policy conclusions.

1. Towards a Knowledge-Based Economy: What's New?

The concept of technological progress, through innovating activities and knowledge creation, as the main engine for economic growth, is not a new one in economics. Its importance was already stressed and at the core of economic thinking from the late eighteenth century on. We only have to consider the dominant role given to technological progress by classical economists such as Karl Marx or this century by Joseph Schumpeter, to realise that economists have always been aware of the crucial importance of innovation and knowledge accumulation for long-term growth.[3] However, three features seem to be the basis of the current, renewed importance given to knowledge for economic growth and welfare.[4]

First, the economic profession has started to recognize the fact that knowledge accumulation can be analysed like the accumulation of any other capital good. That one can apply economic principles to the production and exchange of knowledge; that it is intrinsically endogenous to the economic and the social system and is not an external, black box factor, not to be opened except by scientists and engineers. Hence, while knowledge has some specific features of its own, it can be produced and used in the production of other goods, even in the production of itself, like any other capital good. It also can be stored and will be subject to depreciation, when skills deteriorate or people no longer use particular knowledge and forget. It might even become obsolete, when new knowledge supersedes and renders it worthless.

---

[3] Recently Schumpeter's insights have been picked up and formalized by scholars in the field of (endogenous) growth models. Examples are Segerstrom, Anant and Dinopoulos (1990), Romer (1990), Grossman and Helpman (1991), Aghion and Howitt (1988) and (1992) and Caballero and Jaffé (1993). An excellent overview of these modern Schumpeterian approaches is given in Aghion and Howitt (1998).

[4] See also Soete and Ter Weel (1999) for an analysis of the 'new' economics of innovation and knowledge creation.

However, there are some fundamental differences with traditional material capital goods. First and foremost, the production of knowledge will not take the form of a physical piece of equipment but is generally embedded in some specific blueprint form (a patent, an artefact, a design, a software program, a manuscript, a composition) or in human beings and even in organisations. In each of these cases there will be so-called positive externalities: the knowledge embodied in such blueprints, people or organisations cannot be fully appropriated, it will with little cost to the knowledge creator flow away to others. Knowledge is from this perspective a non-rival good. It can be shared by many people without diminishing in any way the amount available to any one of them. Of course there are costs in acquiring knowledge. A current central theme in economic theory is what is referred to as information asymmetry: the person wanting to buy something from someone who knows more about it, obviously suffers from an asymmetry in information.

This explains why markets for the exchange of knowledge are rare and why most firms have preferred to carry out R&D “in-house” rather than have it contracted out or licensed. It also provides a rationale for policies focussing on the importance of investment in knowledge accumulation, as we discuss later on. Such investments are likely to have high so-called social rates of return, often much higher than the private rate of return: investment in knowledge cannot be simply left to the market.

Second, the growing economic and policy consensus on the importance of knowledge for industrial competitiveness is closely related to the emergence of a cluster of new information and communication technologies (ICTs), which have resulted in a dramatic decline in the price of information processing; in a technological driven digital convergence between communication and computer technology; and last but not least a rapid growth in international electronic networking.

ICTs are in the real sense of the word an information technology, the essence of which consists of the increased memorisation and storage, speed, manipulation and interpretation of data and information. In short, it is what has been characterized as the codification of information and knowledge. As a consequence information technology makes codified knowledge, data and information much more accessible than before to all sectors and agents in the economy linked to information networks or with the knowledge how to access such networks. This is not to deny the importance of tacit knowledge; on the contrary as more and more knowledge becomes codifiable, the remaining non-codifiable part becomes even more crucial.

The ability to codify relevant knowledge in creative ways thus acquires strategic value and will affect competitiveness at all levels. Network access as well as the competence to sort out the relevant information and to use it for economic purposes become of critical importance for performance and income distribution. Specific skills referring to the use of information become of strategic importance. More routine skills by contrast might become totally codifiable and their importance might be reduced dramatically.[5] While the idea of ICTs as a skill-biased technical change, does not consequently capture very well the complexities of the accompanying required de- and reskilling processes, it points nevertheless to the importance of the distributional impact of ICTs.

As a consequence of the increased potential for international codification and transferability, ICT

[5] In contrast, relatively simple human tasks (gardening) might never become codifiable.

can be considered as the first truly global technology. The possibility of ICT to codify information and knowledge over both distance and time, brings about more global access. Knowledge, including economic knowledge becomes to some extent globally available. While the local capacities to use or have the competence to access such knowledge will vary widely, the access potential is there. ICT, in other words, brings to the forefront the enormous potential for catching-up, based upon cost advantages and economic transparency of (dis-)advantages, while stressing at the same time the crucial tacit and other competence elements in the capacity to access international codified knowledge. For technologically leading countries or firms this implies increasing erosion of monopoly rents associated with innovation and shortening of product life cycles.

Furthermore, globalization does not merely represent an extension of opportunities from the national to the world level. It also generates new constraints. Applications of information-related technologies at national level will need to be fully compatible with international trends to avoid the risk of cut-off from vital economic flows. Progress in the ability of firms to customize production will paradoxically multiply the number of mini-markets within the global market, and thus require new marketing skills and new types of interaction with customers. The security of the new world networks acquires strategic importance. Beyond the new legal framework that is required, the operation of international information flows in real time will need to be based on relations of trust between partners that will directly affect the distribution of tasks within firms and between firms. This might reduce the ability of each economic actor to innovate single-handedly in certain key areas.

Third, we would argue that the perception of the nature of innovation processes has also changed significantly over the last decade. Broadly speaking, innovation capability is seen less in terms of the ability to discover new technological principles, and more in terms of the ability to exploit systematically the effects produced by new combinations and use of pieces in the existing stock of knowledge. This new model implies to some extent more routine use of a technological base allowing innovation without the need for leaps in technology. It requires systematic access to the state-of-the-art; each industry must introduce procedures for the dissemination of information regarding the stock of technologies available, so that individual innovators can draw upon the work of other innovators. This mode of knowledge generation - based on the recombination and re-use of known practices - raises much more information-search problems and must confront the problems of the impediments to accessing the existing stock of information that are created by intellectual property right laws.[6]

The science and technology system is in other words shifting towards a more complex socially distributed structure of knowledge production activities, involving in particular a great diversity of organizations having an explicit goal of producing knowledge (learning entities). The old system by contrast, was based on a simple dichotomy between deliberate learning and knowledge generation (R&D laboratories and universities) and activities of production and consumption where the motivation for acting was not to acquire new knowledge but rather to produce or use effective outputs. The collapse (or partial collapse) of this dichotomy conducts to a proliferation of new places having the explicit goal of producing knowledge and undertaking deliberate research activities.

[6] Problems raised by the increasing costs induced by the functions of storing, retrieving, evaluating and using knowledge.

These three changes in perception presents policy makers with a formidable challenge. A challenge which brings back investment in knowledge accumulation, whether it is through education, research, knowledge transfer and diffusion or simply investment in learning back on the top of the policy agenda. We would argue that the field of economics, known as Schumpeterian economics - both of the formal new growth types, as well as the aggregative theorizing type - can be extremely valuable in setting out the focus, relevance and nature of technology and innovation policies.[7]

[7] Innovation and technology policy is defined here on the basis of the definition used by Mowery (1992) as "policies that are intended to influence the decisions of firms (and we would add, public agencies and enterprises) to develop, commercialise or adopt new technologies."

2. On the Growing Policy Relevance of Schumpeterian Approaches to Economics

It is well-known that Joseph Schumpeter held two different approaches of the innovative process. In his first contributions, the emphasis was mainly on the role of new entrepreneurs entering niches of markets. By introducing new ideas and by innovating, these entrepreneurs challenged existing firms through a process of "creative destruction", which was regarded as the engine behind economic progress (Schumpeter, 1912). In later contributions, Schumpeter (1942) paid mainly attention to the key role of large firms as engines for economic growth by accumulating non-transferable knowledge in specific technological areas and markets. This view is sometimes referred to as "creative accumulation"[8]

> *"... the incorporation of endogenous scientific and technical activities conducted by large firms. There is a strong positive feedback loop from successful innovation to increased R&D activities setting up a virtuous self-reinforcing circle leading to renewed impulses to increased market concentration."* (Freeman and Soete, 1987)

2.1. Regimes

The influential contribution of Nelson and Winter (1982) to model Schumpeterian technological regimes was primarily concerned with the basic mechanics of Schumpeterian competition, particularly innovative and imitative strategies and their influence on the evolution of industrial structures. Winter (1984) extended this model with endogenous entry and adaptive R&D

[8] See e.g. Malerba and Orsenigo (1993).

strategies of firms, which emphasized the main characteristics of Schumpeter Mark I and Schumpeter Mark II technological regimes. Schumpeter Mark I is characterized by the key role played by new firms in innovative activities, i.e. creative destruction, whereas in the second one, Schumpeter Mark II, this key role is fulfilled by the large and established firms, i.e. creative accumulation.

The differences between the two regimes have been described by Malerba and Orsenigo (1993) in terms of a combination of four factors: (i) the opportunity and (ii) appropriability conditions, (iii) the cumulativeness of innovative activities and (iv) the nature of knowledge. Given such differences, industries are likely to differ with respect to their dynamic and structural properties, what would be termed "technological regimes".[9]

In this regard opportunity conditions refer to the likelihood of innovating, given a certain research effort. This may depend on e.g. the extent to which a sector can draw from the knowledge base, the technological advances of its suppliers and customers, and major scientific advances in universities or research labs. Appropriability conditions reflect the possibilities of protecting innovations from imitation and of appropriating the profits from an innovation. Possible appropriability devices are patents, secrecy, lead times, costs and time required for duplication, learning curve effects, superior sales efforts, and differential technical efficiency due to scale economies. Cumulativeness conditions refer to the extent to which the innovative successes of individual firms are serially correlated. They are related to the cognitive nature of the learning

[9] Oltra (1998) shows in this respect that the nature of knowledge and the characteristics of the technological environment determine the patterns of innovative activities and the evolution of industrial structure. Van Dijk (1998) tests whether differences in dynamic and structural properties actually exist, by using firm-level data on the manufacturing sector, and observes that these properties of the industries are strongly related to the underlying technological regimes.

process, e.g. learning by doing, and depend on the extent to which technological progress or major advances depend on the current technology stock (see e.g. Nelson, 1995). Finally, with regard to the properties of the knowledge base, Dosi, Freeman and Nelson (1988) distinguish between three aspects of knowledge: (i) the level of specificity, reflecting that knowledge can be applied universally, (ii) the level of tacitness, referring to the extent to which knowledge is well articulated or whether it is more tacit, and (iii) the extent to which the knowledge is publicly available, e.g. scientific and technical publications.

In the literature on technological regimes, opportunity conditions do not necessarily differ between the two regimes.[10] The differences are mainly related to differences in appropriability, cumulativeness conditions and patterns of access to knowledge. A Schumpeter Mark I regime is often characterized by low appropriability and cumulativeness conditions, and the knowledge is mainly (firm) specific, codified and simple. In a Schumpeter Mark II regime these conditions are the opposite: appropriability and cumulativeness conditions are high, while knowledge is mainly generic, tacit and complex.

2.2. Modelling Schumpeterian Regimes

One may now use the distinction between the two metaphorical archetypes of technological regimes underlying the analysis of the previous section for some broader macroeconomic growth insights. We focus on the process of innovation and the accumulation of (both tacit and codified)

[10] Although it should be noted that there exists a positive correlation between the size of the firm and effort put in the R&D process if we investigate this relationship industry by industry. Hence firms conducting a lot of R&D have probably better access to the knowledge available in the economy because they are closer to the leading- edge technologies.

knowledge by constructing a simple schematic model, inspired by the work of Aghion and Howitt (1998) and Caballero and Jaffé (1993). The latter authors have constructed a model of economic growth through the creation of new goods, in which the phenomena of creative destruction and knowledge spillovers play major roles.

Model

Figure 1 shows a simple diagram, which serves as benchmark for the analysis in this section. It is an economic model with just one final good, which can only be consumed and which is produced by a continuum of intermediate goods, indexed on the unit interval. More specifically, the flow of final goods that can be produced using intermediate good *i* at date *t* depends only on the flow x_{it} of intermediate good *i* that is put into the production process, according to the production function

$$Y_{it} = A_{it} x^{\alpha}_{it}, \tag{1}$$

where the parameter A_{it} represents the productivity of the latest generation of intermediate good *i*. Aggregate (or final) output of the final good is the sum

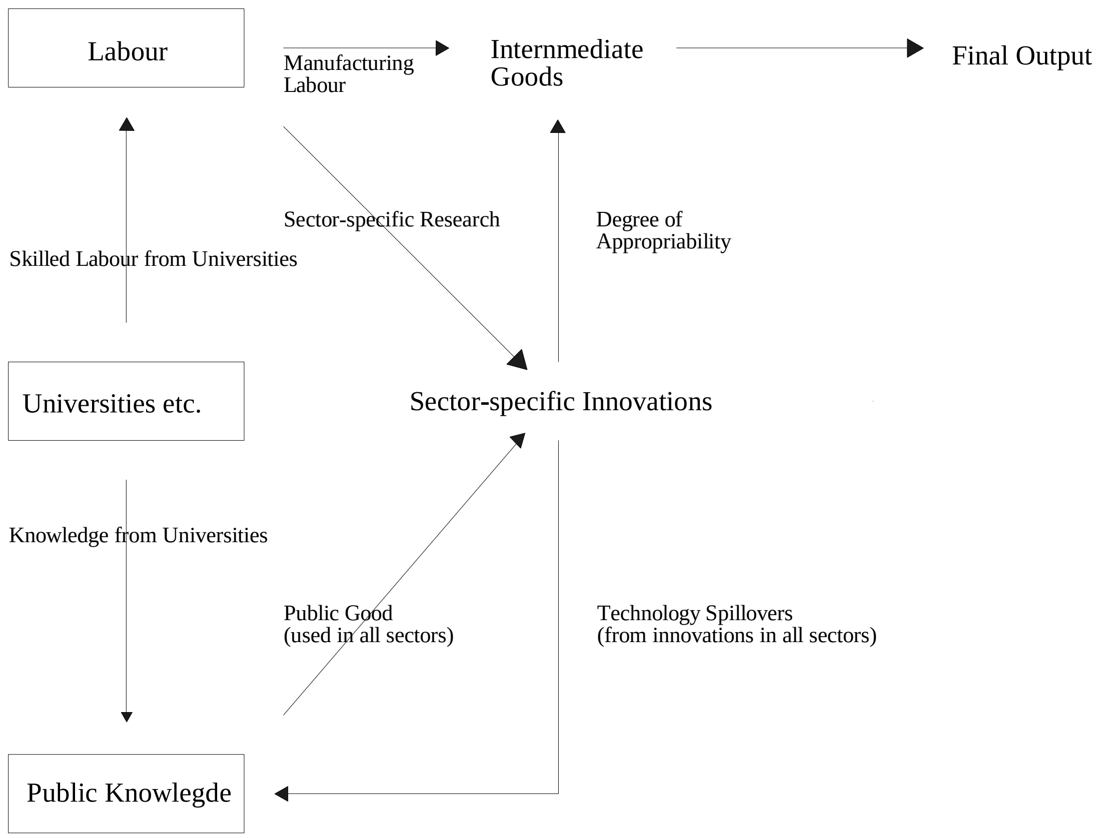
$$Y_t = \int_0^1 Y_{it} di. \tag{2}$$

The state of knowledge in this figure is represented by a so-called leading-edge technology whose productivity parameter at date *t* is A_t^{max}. Each innovation at date *t* in any sector *i* permits the innovator to start producing in sector *i* using the leading-edge technology. The previous incumbent in sector *i*, whose technology is no longer on the leading edge will be displaced. When this happens the technology parameter A_{it} in that sector will jump to A_t^{max}.

Along the lines of Figure 1 one may now analyse the two regimes identified above from the perspective of knowledge creation and accumulation.

Figure 1

A Schematic Presentation of Economic Activities in a Schumpeterian Setting



Source: Adapted from Aghion and Howitt (1998)

Schumpeter Mark I

In the previous section we stated that a Schumpeter Mark I regime is characterized by low appropriability and cumulativeness conditions, and that the knowledge is mainly (firm) specific, codified and simple. Appropriability is represented in Figure 1 by the arrow from innovations to intermediate goods x_{it}. If appropriability is low it means that it is difficult for entrepreneurs to patent their inventions and to reap the fruits from their innovative activities by means of monopoly rents earned on their intermediate goods. Hence, innovations will flow via technology spillovers into the public knowledge basin A_t present in the economy at date t.

This observation brings us to the argument that diffusion of knowledge will be central to growth. Once the contribution of the innovation is leading-edge technology every other entrepreneur is able to use this leading-edge technology. The process described leads then to what is called creative destruction: every time a new entrepreneur enters the market with a new leading-edge technology the incumbent firm whose technology is no longer on the leading edge will be displaced. The fact that the incumbent is displaced is reenforced by the fact that the cumulativeness of innovations is low, for it is hard in a Schumpeter Mark I regime to remain the on the leading edge and therefore to build further on experience and past innovative activities. Basically, what cumulativeness enhances, is the creation of technological environments characterized by continuity in innovative activities and it is hence practically impossible to observe cumulativeness in a Schumpeter Mark I regime.

Schumpeter Mark II

A Schumpeter Mark II regime is characterized by high levels of patenting and hence creates monopoly rents in the intermediate goods sector. This high level of appropriability leads to less spillovers in a Schumpeter Mark II regime than in a Schumpeter Mark I regime, reinforcing the tacitness of knowledge.

Cumulativeness of innovations entails increases in productivity, which itself leads to higher profits. As a consequence, an innovative firm benefits from a higher capacity to invest in R&D, which increases its absorptive capacity and its probability to innovate and imitate in the future. Thus an innovative firm is more likely to get an innovative draw in the future. According to the extent of this effect, the innovative process is more or less cumulative. Since in a Schumpeter Mark II regime cumulativeness is higher due to experience and past innovative activities - as a consequence of creative accumulation - firms in this regime are large and entrance is unlikely due to both the high level of concentration in the particular market and to knowledge gap present among possible entrants.

Finally, with respect to public knowledge A_t we can note that spillovers are used by firms in a Schumpeter Mark II regime to innovate, but that technology spillovers between firms are marginal because of the high degree of appropriability of innovative activities. Strategic alliances are likely to reinforce the closed accumulation process of the Mark II type, rather than involve real "creative destruction"-spillovers. Hence it is more profitable for firms in a Schumpeter Mark II regime to perform R&D than it is for firms in a setting of creative destruction where spillovers are widely applied and profit levels are tending towards zero.

The two archetypes discussed here should be viewed as two extreme theoretical cases of technology accumulation. They are nevertheless helpful in giving some broad hindsight as to the fundamental difference in the need for and the sort of public support. In the case of Schumpeter Mark I one may think of a need for access to finance for R&D particularly for small and medium sized firms and new technology based firms; of the particular importance of science and technology "distribution" power to use David and Foray's term of the national innovation system (links between universities and public research labs and private firms, etc.; possibly assistance with patenting; and more generally support for technological diversity and dynamism. In the case of the Schumpeter Mark II archetype, the policies are likely to be of the exact opposite kind: greater emphasis on diffusion, sub-contracting of research, spin-offs and spin-outs; possibly reducing some of the appropriability conditions; etc.

Before turning to some of these broader policy issues, we turn now however to some facts and figures.

3. From R&D to Knowledge Investment: Facts and Figures

It is agreed upon that R&D plays a significant role in explaining economic growth. Many empirical studies have established this conclusion for OECD countries.[11] Table 1 shows R&D spending in the business sector for several OECD countries as a percentage of GDP from 1983 to 1996 (if available). From this table we observe that spending on R&D has remained fairly constant over time.

Table 1: R&D in the Business Sector as a Percentage of GDP

Country	1983	1985	1990	1995	1996
Netherlands	2.02	2.09	2.15	2.09	2.10
Belgium	1.58	1.64	1.66[2]	..	1.62
Germany	2.51	271	2.75	2.27	2.26
France	2.11	2.25	2.41	2.34	2.28
UK	2.25	2.28	2.23	2.19[4]	1.98
Norway	1.41	1.62	1.84[2]	1.59	..
Sweden	2.56	2.89	2.89[2]	3.04	3.61
Denmark	1.19	1.25	1.63	1.83	2.00
Switzerland	2.28	2.88[1]	2.86[3]	2.68[5]	..
US	2.71	2.92	2.81	2.58	..
Japan	2.56	2.81	3.04	2.84[4]	..

[1] 1986, [2] 1991, [3] 1989, [4] 1994, [5] 1992, .. not available

Source: OECD (1995)

[11] See e.g. recent studies by Coe and Helpman (1995), Coe, Helpman and Hoffmaister (1997) and Engelbrecht (1997). Coe and Helpman (1995) study international R&D spillovers in a long-run equilibrium model and conclude that R&D spillovers play a prominent role in the explanation of productivity growth and productivity convergence across countries. This long-run equilibrium model is a useful tool to investigate the extent to which a country's productivity level depends on domestic and foreign R&D and foreign R&D capital stocks. Bernstein and Mohnen (1991) have shown that it is important to account for temporary deviations from long-run equilibrium growth paths in measuring productivity growth because simply assuming that producers are always employing their long-run equilibrium capital stock can lead to biases in measured productivity growth. Bernstein and Mohnen (1998) account for these deviations from long-run equilibrium by using adjustment costs. Their results are in line with other studies associated with domestic R&D spillovers - cf. Griliches (1992), as well as the social rates obtained by Coe and Helpman (1995) in a multi-country context.

In modern growth theory the existence of R&D or more broadly knowledge externalities in R&D, leads to the conclusion that the equilibrium growth rate is lower than the optimal growth rate. In other words there will be, if left to the market, underinvestment in knowledge and R&D in particular and hence a case for government support (e.g. subsidies to R&D) to increase the equilibrium growth rate up to the level of the optimal growth rate.[12] This underinvestment is made most explicit with respect to the basic research or general knowledge part of the innovation process.[13] The latter is generally separated out in endogenous growth models in a blueprint part which can be appropriated through monopoly power and which thus brings about a strong incentive to produce innovations and invest in R&D, and a general knowledge part which flows over to other producers of blueprints. It is mainly the latter part which creates the growth externalities and in which the underinvestment takes place, pointing again as in the old seminal papers of Nelson (1959) and Arrow (1962) to the role for government and public support for basic research.

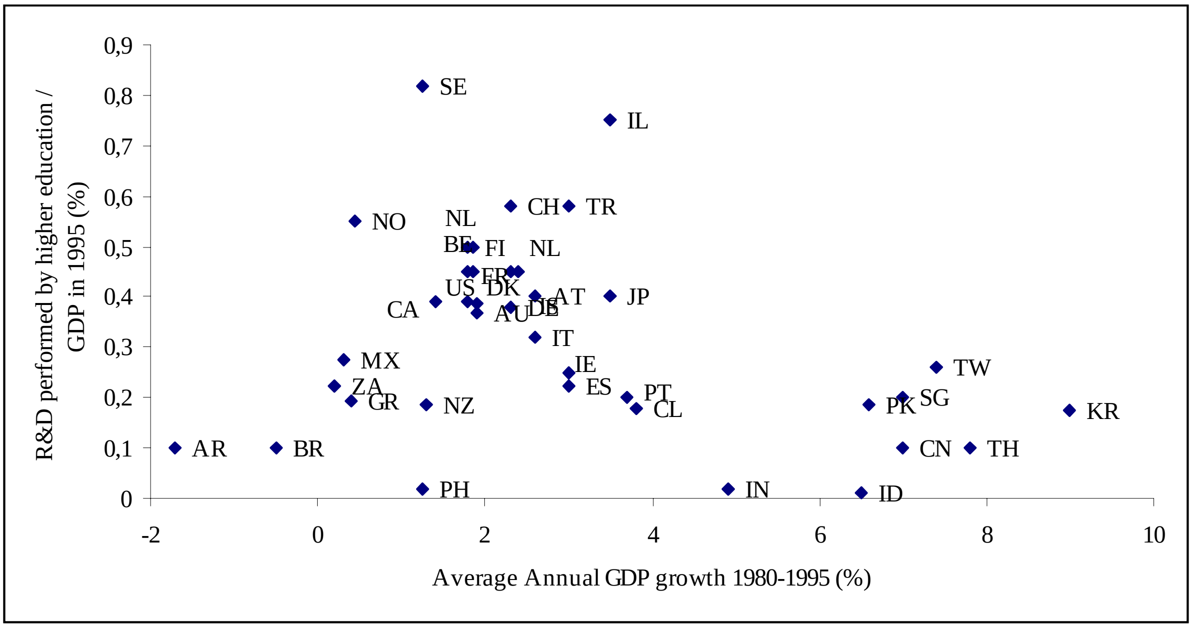
It would be unfortunate, particularly given the quite substantial and rich science and technology policy literature which has emerged over the last thirty years, to reduce the relevant policy issues to a debate about the volume of public financial support aimed at capturing the elusive knowledge externalities from basic research or other general knowledge. As a matter of fact, and as illustrated in a very approximated way in Figure 2, one could reasonably argue that from a

[12] The point can be best illustrated by arguing that a paradox is emerging between the new found formal believe in the importance of the increasing returns associated with research and ideas, identified e.g. in terms of rivalness and appropriability, and the empirical evidence about the contribution of R&D - and in particular the public support for R&D - to output and productivity growth, see e.g. Romer (1993).

[13] The actual design and implementation of such policies have of course received much renewed attention with the new found theoretical wisdom associated with new growth theory. Unfortunately, as Nelson (1994) in particular has been quick to emphasize new growth theory has so far failed to include much of the appreciative theorizing around technology policy and in particular the importance of so-called “national systems of innovation”. See e.g. Freeman (1987), Nelson (1993) and Lundvall (1993).

simple cross country point of view, there is no evidence of any relationship, worse if anything there appears more of a negative relationship between government support for research and economic growth.

Figure 2
Relationship between Higher Education Resource Intensity and Growth, 1980-1995



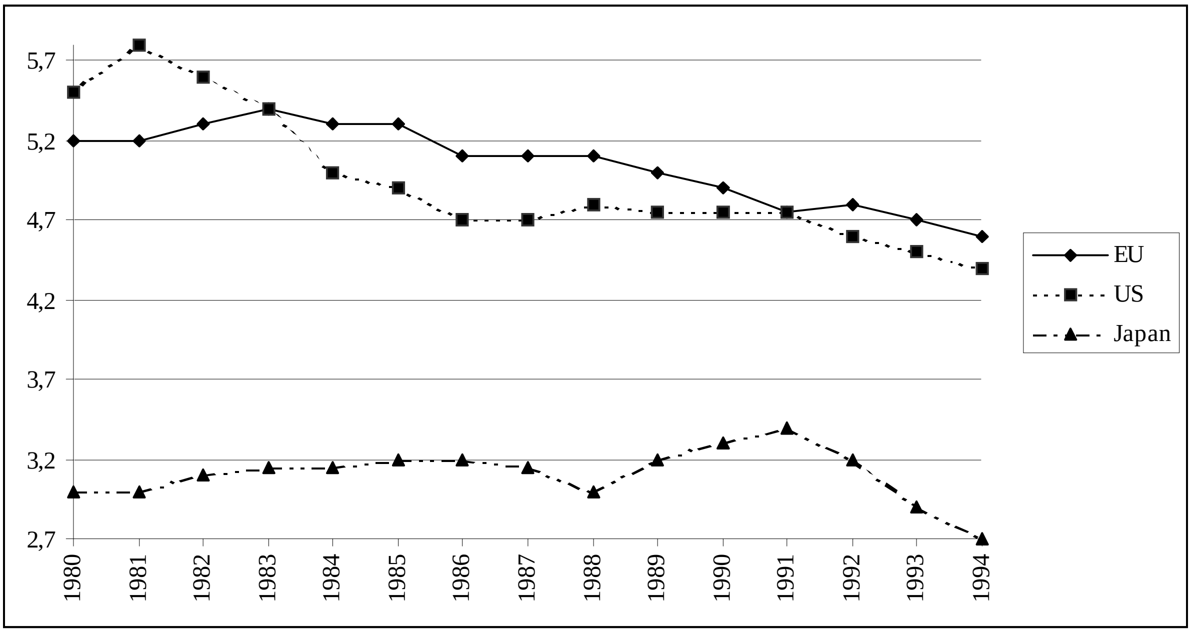
Countries: AT Austria; AR Argentina; AU Australia; BE Belgium; BR Brazil; CA Canada; CH Switzerland; CI Chile; CN China; DE Germany; DK Denmark; ES Spain; FI Finland; FR France; GD United Kingdom; GR Greece; ID Indonesia; IE Ireland; IL Israel; IN India; IS Iceland; IT Italy; JP Japan; KR Korea; MX Mexico; NL Netherlands; NO Norway; NZ New Zealand; PH Philippines; PK Pakistan; PT Portugal; SE Sweden; SG Singapore; TH Thailand; TR Turkey; TW Taiwan; US United States and ZA South Africa.

Source: EU (1997)

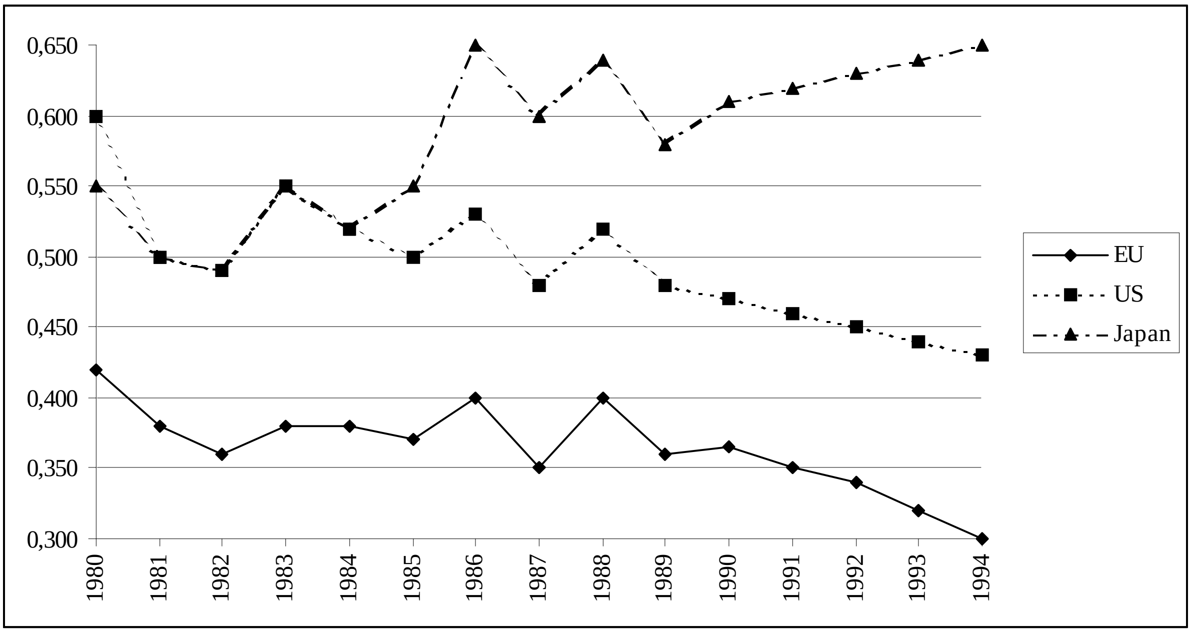
In Figure 2, the proportion of total (civilian) research funded by governments is related to some measure of economic growth for about forty countries for which such data was readily available (EU, 1997). The (non-significant) negative relationship appears valid for the group of developed OECD economies as well as for the other most research active developing countries in the world. The approximative evidence presented in the figure is actually supported by more formal econometric evidence which has systematically pointed to the fact that government R&D support did not have a significant impact on the productivity (TFP) growth of enterprises (Griliches, 1984, Lichtenberg and Siegel, 1991), sectors or countries (Lichtenberg, 1992). In all these cases the estimated coefficients for government financed investments in R&D were, in contrast to private financed R&D non-significant, in some cases even negative (Lichtenberg, 1992).

In a similar approximative way, it can be illustrated that Europe's comparative international weakness in the science and technology area is less related to the basic, primarily government funded, research part than to the more market driven, more technology related, applied part. Thus as illustrated in Figure 3, the EU has continued over the 1980s to witness a high scientific productivity performance, as approximated through the number of scientific publications per million ECU spent on non-business R&D, roughly similar to the US, but way above Japan and the Dynamic Asian Economies. By contrast, the EU's technological productivity performance, as approximated through the number of US patents granted per million ECU business performed R&D, has continued to lag behind comparable US and Japanese ratios.

Figure 3
Trends in Science and Technology Performance, 1980-1994



a Publication/Non-business R&D Ratio
(number of publications per non-business R&D, million ECU in 1987 prices)



b US Patent/Business R&D Ratio

(Number of US patents per business R&D, million ECU in 1987 prices)

Source: EU (1997)

There are obviously many methodological problems in interpreting the sort of productivity measures presented in Figure 3: much R&D performed in the business sector is also oriented towards basic and fundamental research and similarly much research performed in the higher education and government sectors will also lead to patenting activity. Furthermore, there are major sectoral differences in patent propensity of R&D: one may think of the difference between aerospace, pharmaceuticals and metal working. Such differences are likely to be reflected in the aggregate country ratios.

Nevertheless, the rough approximations presented in Figure 3, shed some interesting light on the apparent large differences in S&T productivity between the EU, the US and Japan. The EU appears from this perspective to benefit from a highly productive and internationally well performing scientific base, roughly at a comparable efficiency levels of the US. By contrast, its technological productivity, as approximated through the number of patents granted per million ECU BERD, was only marginally below that of the US and Japan in 1981 but appears to have steadily deteriorated over the 1980s and 1990s. The actual patent/R&D ratio is now half the Japanese or US ratio. The US by contrast who saw its scientific productivity performance only slightly deteriorate over the 1980s, has witnessed a remarkable reversal in its technological productivity since 1988. The latter is now converging towards Japanese levels. The S&T productivity approximations for Japan, illustrate on the one hand Japan's apparent, relatively poor scientific productivity, slowly improving though and converging towards US and European levels, and Japan's strong and further rising technological productivity.

While the distinction between "science" and "technology", as highlighted above is undoubtedly overdone, it lends further support to the emergence, particularly within the European context, of a “research paradox”: the fact that contrary to economic theory and intuition, a strong scientific research base does not appear to go hand in hand with strong technological and economic performance, rather the contrary. Thus as the aggregate evidence on productivity growth illustrates, the gap between the EU’s labour productivity in manufacturing and US labour productivity has, contrary to Japan, further widened, particularly over the last five years.

At first sight there appears thus contradiction between the new formal theoretical growth wisdom and the formal and less formal empirical evidence. It is within this apparent “paradox framework” that, in our view, national technology policies need to be reassessed and their implications for the international trading system analysed. As a recent paper of Weder and Grubel (1993) illustrates, such a debate might well be framed within “Coasean economics” terms about the emergence of private institutions internalizing R&D externalities. The particular way public policies might encourage the operation of such efficiency enhancing institutions becomes then also a focal point of analysis as is discussed below. However, before drawing such converging policy conclusions, it seems essential to bring together the more appreciative evidence detailing the wide diversity of national science and technology policies and institutions, including the historical growth and emergence of corporate and public research laboratories, private and public universities, copyright and patent institutions, as well as other public and private institutions dealing with inter-firm and industry-university research collaborations. Such international comparative analyses of science and technology related institutions, of institutional innovations and of institutional rearrangements are in our view invaluable in our search for new international institutional learning.[14]

---

[14] For an excellent survey at providing such evidence, see David and Foray (1995).

4. Policy Conclusions

As we saw in the first section of this paper, there is growing recognition that knowledge, both as an input and output, is central to the process of growth and wealth accumulation. As a recent OECD document put it: “Knowledge in all it forms plays today a crucial role in economic processes. Intangible investment is growing much more rapidly than physical investment. Firms with more knowledge are winners on markets. Nations endowed with more knowledge are more competitive. Individuals with more knowledge get better paid jobs. This strategic role is at the root of increasing investments by individuals, firms and nations in all forms of knowledge.” (OECD, 1995). In short, most contemporary developed economies are and have increasingly become “knowledge-based”.

Growth theory has traditionally recognized the crucial role of knowledge accumulation in the growth process. Without technological change, capital accumulation will not be sustained - its marginal productivity declining - and the equilibrium (per capita) growth of the economy will inexorably tend towards zero. It are the inventions of new machines and intermediate goods which provide the opportunities for new investment. Thus, as has been shown in many empirical studies, the efficiency gains following the introduction, diffusion and continuous improvements of new production processes, have been the major factor behind the rise in real wages over the post-war period in the OECD economies.

However, not only physical but also human capital accumulation depends on technological change. Whereas the embodiment of technology in physical capital has long been recognised, the increasing importance of the “embodiment” of technology in people has been recognised much more recently (Schultz, 1961). Yet there is little doubt that the way to use a particular technology is fully part of that technology. Human skills are essential complementary assets to implement, maintain, adapt and use new physically embodied technologies. From this perspective human capital and technology are two faces of the same coin, two non-separable aspects of knowledge accumulation. The accumulation of human capital can involve both an increase in the knowledge embodied in skilled workers and an increase in the number of skilled workers.

The recognition of the importance of this much broader notion of knowledge accumulation - including alongside such capital and human “embodied” technological change, also “disembodied” technological change - is challenging the traditionally segmented “market failure” policy approach to science and technology support. As we argued in Section 2, from this broader approach policies with regard to technological chance encompass not just R&D, but the whole spectrum of scientific and technological activities from invention to diffusion, from basic research to technological mastery. Such a view of technological change rejects the orthodox economics definition of technological capabilities in terms of ‘knowledge’ or ‘information’ with the connotation that industrial technology is like a recipe; understood by particular individuals and readily articulatable and communicable from one individual to another with the requisite background training. From a Schumpeterian perspective, what is written down - the recipe, the textbook discussion, the patent - provides a start, but only in the sense that a recipe provides a start. Knowing how to produce a product, is as much experienced tacit skill as articulatable knowledge. And contrary to the implicit general theory the tacit skills of one ‘skilled in the art’ are not interchangeable: who works with the recipe makes a difference.

At a more general level, such a view point to the importance of the technical as well as social integration of technological change: within firms as much as within society at large. The implicit idea in the orthodox economics view of technology that what one firm can do, other firms can do too, if they had access to the relevant information, is not only rejected but replaced by the fundamental question about what determines the kinds of technological capabilities firms get under control and how these capabilities do evolve over time.

The hypothesis put forward within the framework of this conference can hence be reinterpreted as follows. Orthodox static competition (or regulation) policy -- with as most explicit expression maybe the OPTA proposals limiting KPN's possibilities for cross-services subsidies -- will intrinsically fail to answer the dynamic challenges raised by technical change. There is bound to be duplication or near duplication of research and development effort. Nelson and Soete (1988, pp. 632-633) put is as follows:

> *"Economies of scale and scope that might be achieved through coordination will be missed. Certain kinds of scientific or technological research that would have high social value simply may not be done because they would not yield proprietary advantage, or because no one is minding the overall portfolio. To the extent that technology is proprietary, many enterprises might be operating inefficiently, even failing at a considerable social cost, for want of access to best technology."*

Dynamic competition which induces private firms to keep on experimenting, to search for solutions to new problems, are, in our view fully and completely part of the notion of technology and innovation policy as espoused here. And while such policies might be more appropriate in particular regimes of technological change as argued in Section 2, it must be clear that they are an integrated part of the broad technology and innovation policy framework of our emerging knowledge based economies.

But as argued in Section 3, the more open, international technology environment of the end of this Century confronts both our country and more generally the EU with a number of new, fundamental challenges in the science, technology and innovation area. To what extent are current technology policies, both in individual EU Member Countries and at the EU supra-national level, in their priority setting, design and implementation well suited to respond to these new challenges? What is indeed the effectiveness of such policies? Is there scope for complementarity between S&T policies at different levels of implementation (regional, national, supra-national)? Or do such policies lead to large substitution effects?

It was not the place here to try to answer these questions. Rather to highlight, that in the end little is known about the effectiveness of the various science, technology and innovation policies implemented in the different European countries and the EU. Whereas at the national level many detailed analyses have been carried out evaluating and monitoring particular policy instruments and hence assisting policy makers in continuous institutional learning, we are particularly concerned with the response (or rather lack of response) of European technology policies to the new policy challenges raised above.

Thus, and keeping in mind that this is by and large a non-exhaustive list, the question can be raised whether the concept of “pre-competitive research”, popular in many European S&T policies, is still of any relevance to the more systemic way in which science and technology appear to interact to-day,[15] or whether the “pre-competitive” concept has actually reinforced the European “research paradox” described in Section 3 with public support for those research activities for which applications could not be thought of. Similarly, the question can be raised whether the 50/50 principle of public/private support has not practically automatically led to the substitution of private R&D funding of the least profitable R&D activities, furthest removed from individual firms’ core R&D and competitive strength areas; just as the 100% principle in the case of universities or public research laboratories might have led to substitution of national funds for EU Framework Programme funds. Similarly, and interacting with the broader aims of social cohesion, the question can be raised whether the large flow of R&D Community funding to the peripheral countries, representing in some countries such as Greece already 60% of total business enterprise R&D efforts, is in the end going to bring about an indigenous S&T development in those countries? Finally, the question can be raised whether the desire for European networking, collaboration and coordination in the S&T area, isn't reinforcing what are already national strongholds in science and technology (the so-called Matthew effect), rather than raising the overall level of European science and technology.

The major problem in answering these questions, is that mechanisms of control in many of these fields are often lacking; that proper evaluation of the policies implemented and their effectiveness is often impossible given the lack of available data and that the fear of directed, to some extent accountable, policy actions, has led to neutral, ineffective policy modes of operation. There is consequently, an urgent need to rethink the mechanisms of implementation, of priority setting and of control and evaluation.

[15] See e.g. Soete and Arundel (1993).

At a more general level, the question can be raised whether European technology policies shouldn't be fundamentally redesigned. We would argue that within the emerging framework of a European monetary union, it will be essential to have policies aimed at increasing mobility across Europe. Of particular importance to European competitiveness will be the mobility of researchers: scientists and engineers in particular. Characteristic of European research (and in particular publicly funded research) is indeed its fragmented nature and small country bias with a multitude of relatively small research institutes being spread over a very widespread field of different disciplines. A European innovation policy might hence start to focus explicitly on the various barriers to such mobility. One might think e.g. of an explicitly mobility related European status for European expatriate research personnel comparable to the status of European civil servant and providing a common, harmonized social security, pension and fiscal system to such European researchers. Some elements of this notion were already advanced in the Green Paper on Innovation, but rejected by member states. In emerging “Euroland”, labour market fragmentation particularly of high skilled labour qualifications is likely to be most damaging for economic growth and competitiveness. Why would not the Netherlands with its open international scientific and research community take this policy initiative?

References

Aghion, P. and P. Howitt (1988), *Growth and Cycles through Creative Destruction*, MIT Mimeo, Cambridge MA.

Aghion P. and P. Howitt (1992), 'A Model of Growth through Creative Destruction,' *Econometrica*, 60, pp. 323-351.

Aghion, P. and P. Howitt (1998), *Endogenous Growth Theory*, Cambridge MA, MIT Press.

Arrow, K. J. (1962), 'The Economic Implications of Learning by Doing,' *Review of Economic Studies*, 29, pp. 155-173.

Bacon, F. (1627), *The New Atlantis*.

Bernstein, J. I. and P. Mohnen (1991), 'Price-Cost Margins, Exports and Productivity Growth with an Application to Canadian Industries,' *Canadian Journal of Economics*, 24, pp. 638-659.

Bernstein, J. I. and P. Mohnen (1998), 'International R&D Spillovers between US and Japanese R&D Intensive Sectors,' *Journal of International Economics*, 44, pp. 315-338.

Caballero, R. J. and A. B. Jaffé (1993), 'How High Are the Giant's Shoulders: An Empirical Assessment of Knowledge Spillovers and Creative Destruction in a Model of Economic Growth,' *NBER Macroeconomics Annual*, Cambridge MA, MIT Press.

Coe, D. T. and E. Helpman (1995), 'International R&D Spillovers,' *European Economic Review*, 39, pp. 859-887.

Coe, D. T., E. Helpman and A. Hoffmaister (1997), 'North-south R&D Spillovers,' *Economic Journal*, 107, pp. 134-149.

Cohen, W. M. (1995), Empirical Studies of Innovative Activity, in: Stoneman, P. (ed.), *Handbook of the Economics of Innovation and Technological Change*, Blackwell, Oxford.

David, P. A. and D. Foray (1995), 'Accessing and Expanding the Science and Technology Knowledge Base,' *STI Review*, 16, Paris, OECD.

Ergas (1987), 'Does Technology Policy Matter?,' in: B. Guile and H. Brooks (eds.), *Technology and Global Competition*, Washington, National Academy Press.

EU (1996), *The Green Book on Innovation*, Brussels, EU.

EU (1997), *Second European Report on S&T Indicators*, Brussels, EU.

Freeman, C. (1987), *Technology Policy and Economic Performance: Lessons from Japan*, London, Pinter.

Freeman, C. and L. L. G. Soete (1997), *The Economics of Industrial Innovation*, Third Edition, London, Pinter.

Griliches, Z. (1984), *R&D, Patents and Productivity*, Chicago, University of Chicago Press.

Griliches, Z. (1992), 'The Search for R&D Spillovers,' *Scandinavian Journal of Economics*, 94, pp. s29-s47.

Grossman, G. M. and E. Helpman (1991), *Innovation and Growth in the Global Economy*, Cambridge MA, MIT Press.

Kealey, T. (1998), 'Why Science Is Endogenous: A Debate with Paul David (and Ben Martin, Paul Romer, Chris Freeman, Luc Soete and Keith Pavitt)', *Research Policy*, vol. 26, no. 7-8, pp. 897-923.

Lichtenberg, F. (1992), *Corporate Takeovers and Productivity*, Cambridge MA, MIT Press.

Lichtenberg, F. and D. Siegel (1991), 'The Impact of R&D Investment on Productivity: New Evidence Using Linked R&D-LRD Data,' *Economic Inquiry*, 29, pp. 203-229.

Lundvall, B.-Å. (1992), *National Systems of Innovation: An Analytical Framework*, London, Pinter.

Malerba F. and L. Orsenigo (1993), 'Technological Regimes and Firm Behaviour,' *Industrial Corporate Change*, 2, pp. 45-71.

Mowery, D. (1992), 'Survey of Technology Policy,' in: P. Stoneman (ed.), *Handbook of the Economics of Technical Change*, Amsterdam, Elsevier.

Nelson, R. R. (1959), 'The Simple Economics of Basic Scientific Research,' *Journal of Political Economy*, 67, pp. 297-306.

Nelson, R. R. (ed.) (1993), *National Systems of Innovation: A Comparative Study*, Oxford, Oxford University Press.

Nelson, R. R. (1994), What Has Been the Matter with Neo-Classical Growth Theory? in: Silverberg, G. and L. L. G. Soete (eds.), *The Economics of Growth and Technical Change*, Edward Elgar, Aldershot.

Nelson, R. R. (1999), Tinbergen Lecture, *De Economist*, Forthcoming 1999.

Nelson, R. R. and S. Winter (1982), *An Evolutionary Theory of Economic Change*, Cambridge MA, Harvard University Press.

OECD (1995), *Technology, Productivity and Job Creation*, Vol. I and II, The OECD Job Strategy, Paris, OECD.

Oltra (1998), *Industrial Dynamics and Diversity in Schumpeterian Technological Regimes*, Paper presented at the ETIC Conference, Strasbourg, 16-17 October.

Romer, P. M. (1990), 'Endogenous Technological Change,' *Journal of Political Economy*, 98, pp. s71-s102.

Romer, P. M. (1993), 'Implementing a National Technology Strategy with Self-Organising Industry Investment Boards,' *Brooking Papers on Economic Activity*, pp. 345-390.

Schultz, T. W. (1961), 'Investment in human capital,' *American Economic Review,* vol. 51, no. 1, pp. 1-17.

Segerstrom, P.S., T. Anant and E. Dinopoulos (1990), 'A Schumpeterian Model of the Product Life Cycle,' *American Economic Review*, 80, pp. 1077-1092.

Soete, L. L. G. and A. Arundel (1993), *An Integrated Approach to European Innovation and Technology Diffusion Policy: A Maastricht Memorandum*, Brussels, EU.

Soete, L. L. G. and B. J. ter Weel (1999), Innovation, Knowledge Creation and Technology Policy in Europe, *MERIT Research Memorandum 99-001*, Maastricht.

Soete, L. L. G. and R. Turner (1984), *Technology Diffusion and the Rate of Technical Change, Econmic Growth and the Structure of Long-Term Development*, New York, St. Martin's Press.

Van Dijk, M. (1998), *Technological Regimes and Industrial Dynamics: The Evidence from Dutch Manufacturing*, Paper presented at the UNU-INTECH conference on Industrial Structure, Innovation Dynamics and Technology Policy, 16-17 October 1998, Lisbon, Portugal.

Weder, R. and H. G. Grubel (1993), 'The New Growth Theory and Coasean Economics: Institutions to Capture Externalities,' *Welwirtschaftliches Archiv*, 129, pp. 488-513.

Winter, S. (1984), 'Schumpeterian Competition in Alternative Technological Regimes,' *Journal of Economic Behaviour and Organization*, 5, pp. 287-320.